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LIFE

IN ITS

PHYSICAL ASPECTS,

BY

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Animated beings manifest a twofold nature: one is material; the other, spiritual.

The material or physical nature assumes a form, a shape, peculiar in each species, constituting bodies, tangible and visible to the senses; the spiritual nature consists of an immaterial essence, without any form or shape, either visible or tangible to the senses.

Now, whether we call the latter immaterial principle, spirit or soul, it matters not: let us regard it as the condition *sine qua non* of the physical manifestation of animated beings. To its sphere are to be referred the moral acts and the moral tendencies, which belong to the domain of moral philosophy.

Of the physical nature of animated beings alone, we propose to treat in the present memoir: the different phases through which it passes from its first manifestation up to its last stage of existence, constituting what we term the *physical aspects of life*.

The physical aspects of life result from a series of functions; all of which depend on one general function presiding throughout the whole range of animal existence; in other words, *the law under which a physical being starts, is the law under which it lives its whole life through.*

It is therefore proposed, as our chief object, to inquire into the ultimate process of organic life, that is to say, the elaboration of matter, its assimilation, and its passage into the various parts and organs which it constitutes.

Hence the leading thought of this essay may thus be briefly expressed: THE PHENOMENA OF THE ANIMAL ECONOMY TAKE PLACE AS THOUGH THE LIVING FABRIC WERE BUT A FACTORY OF CELLS.

FIRST.—All the organs and tissues are a compound of cells, diversely modified or metamorphosed;

SECOND.—The first aspect under which an animal manifests itself is that of a cell;

THIRD.—The subsequent growth of that animal is a simple multiplication of cells;

FOURTH.—The nourishing process is a mere replacing of decayed or broken up cells, by new ones.

Such is the hypothesis, theory, or law, whichever it may be termed.

I.

Microscopic investigations of animal structures at large, have satisfied most anatomists and physiologists that all organs are a component of cells,—that cells are found at the base of all animal tissues,—that cells are the materials which constitute the entire organic frame.

The actual demonstrations of these facts form a not unimportant branch of general anatomy, upon which much has already been written.

It is therefore not in place here to undertake any structural analysis of organs and tissues, or to enter into any discussion of the cellular doctrine, from which some minds may dissent. We receive it here as philosophical and sound, since our own researches and studies are all in its favor.

The cellular doctrine is the keystone of all that follows; and some of the facts hereafter to be mentioned may tend furthermore towards its illustration.

II.

In the organic structure of animals, there are cells which are primordial in their nature, and other cells which are produced within the latter, and hence may be termed derivative cells.

1st. The *primordial cells* originate through the union of two primary liquids, which combine according to a given principle of reciprocal affinity.

2d. The *derivative cells* are formed within the primordial cells, through the growth of nuclei therein contained, being developed according to the principle of exogenesis.

III.

The experiments of Dr. Ascherson* have made us acquainted with the mode in which primordial cells will form in an artificial way by simply bringing into contact, under the ordinary temperature of animal heat, liquid fat and albumen.

**Müller's* Archiv für Anatomie, Physiologie und wissenschaftliche Medicin. Jahrgang 1840, p. 44; also Comptes-Rendus de l'Institut (Académie des Sciences). Vol. VII, 1838, p. 837.

Liquid fat, or oil, as well as albumen, when examined under the microscope, in their primitive pure state, exhibit that peculiar appearance known as *continuity of structure*: these substances are purely liquid throughout. But no sooner has a contact been effected between them, than cells are instantaneously formed. The examination of these cells has enabled the experimenter to ascertain that the oil or liquid fat (either will do) is the enclosed substance, whilst the albumen constitutes the enveloping substance under the shape of a membrane, the gradual formation of which has been watched, and its process described.

Primordial cells thus artificially obtained are so perfectly similar to the primordial cells formed directly by the animal fabric, that no physiologist could point out the difference.

Yet they are not identical in a philosophical point of view; inasmuch as the artificial cells, isolated as they are from the living fabric, will not make any further progress. Life we cannot impart to them artificially. Vitality is not within the reach of our experiments. We cannot start life mechanically. Still less has matter the power of starting it.

The point of departure of living beings is altogether moral and placed far beyond the sphere of human power and human intellect.

IV.

In order to understand the formation of the derivative cells, we must return to the animal fabric,—which alone can procreate them,—there to witness the primeval shape, the first manifestation of a being that is about to make its appearance upon the stage of life.

Every animal originates from an egg; the ancient adage, "*omne vivum ex ovo*," is true and sound. But the egg, as an egg, is already a being: a being that has undergone various phases, and consequently has a previous history.

The researches respecting the development of the ova, in the various classes of the animal kingdom, have furnished to embryologists the means of establishing beyond any reasonable doubt, that there exists an instant in their history when the eggs are not to be distinguished from the ordinary cells constituting organic tissues;

And that there is another instant, when these cells increase in size, and are storing up within their walls or envelopes generations upon generations of younger cells, thus preparing the egg properly so called.

The process of growth of an organic cell which is destined to become an egg, is as follows: in its interior, nuclei will first make their appearance, which nuclei will grow into as many cellules, within which cellules nucleoli will appear, indicating a third generation of cellules. The latter again will grow in accordance with the same law than their parent

and grand-parent cells themselves grew, and thus, multiplying by exogenesis, gradually build up the yelk sphere.

Now, whenever the third generation of cells appears and developes, the grandmother cell dissolves, setting free its contents; and so on, until the egg is mature.

Partial observations upon the *formation of cells within cells*, were first made by Martin Barry in the third series of his "Researches in Embryology: a contribution to the Physiology of Cells."*

Since our own researches have been directed towards that field of inquiry, every well observed fact has become confirmatory of the doctrine of THE DEVELOPMENT OF CELLS THROUGH THE GROWTH OF NUCLEI; which we hold to be true for the entire animal kingdom.

V.

A period arrives when the egg is mature, that is, full grown. The yelk, then, is composed of minute cells, all uniform in structure, and apparently in a state of absolute quiescence. The egg, thus far, is prepared by the female exclusively. It will, however, not fulfil its destiny without the coöperation of the opposite sex.

We have discussed elsewhere† the probable phenomena attending this period in the history of the ova. These phenomena having no direct bearing upon the leading question treated in the present memoir, we need not dwell upon them.

We take now the egg after the fecundation: the latter is no sooner effected than a new activity is displayed, both in the vitelline or yelk-cells individually, and in the vitelline sphere as a *tout ensemble:*

The yelk sphere undergoes a process of cleavage or division, well known and described; the signification of which, we believe, may be better understood when looked upon as a general kneading of its substance;

And at the same time that this kneading of the entire mass is taking place, the constituent cells, each individually, undergo that process of cellular life alluded to above: a labor of diversification begins amongst these cells, for the building up of various parts—various regions in the embryonic mass.

For, now, the yelk or vitelline sphere has become an embryo. As the embryo progresses in its development, the various organs of which it

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* Phil. Trans. of the Royal Society of London, for the year 1840, p. 529.

† Journ. of the Acad. of Nat. Sciences of Philadelphia. New Series. Vol. II, 1854, with three plates.

will successively be composed make their appearance, in the order of their relative rank. The central and essential, first; then the secondary ones.

When hatched, the new being is provided with various parts, each of which is composed of diversified cells; so much so that a microscopical examination will determine the organ which they constitute.

Now, all this diversity sprang up from a most uniform substance. Substances which a chemical analysis could not have ascertained to exist within the egg, before its fecundation, have successively made their appearance during the development of the embryo.

It may be inquired, whence do these substances come? Did the organism create them, that is to say, make them out of nothing? Surely not. The organism produced them by transforming the homogeneous materials placed under its control. Yet it must be remembered that this transformation takes place through the agency of heat, which is transmitted through the shell or external envelope of the egg. Heat, therefore, plays an important part in the process of the transformation of substances within the organic fabric. And it is not unreasonable to suppose that the atmospheric elements penetrate the egg, imbibing as it were the vitelline substance while being transformed or metamorphosed.

The same doctrine will apply to the formation of the yelk within the original primordial cell. That primordial cell, however, is under the control of the living fabric of the parent, and is surrounded with primary fluids that may greatly assist the production of its substances through the process of endosmosis.

To illustrate this process by an example: the primordial cells—and consequently the primitive eggs—we have stated, are a compound of oil on the one part, and of albumen on the other; the albumen forming the envelope, whilst the oil constitutes the contents. Now, in order to transform the oily contents into cellules, or nuclei which are the first stage of cellules, an addition of albumen seems necessarily required, and that albumen may be considered as entering the primordial envelope by endosmosis.

But here we approach the ultimate and impalpable act of physical life, which escapes observation.

To resume briefly the foregoing chapter: from its immature up to its mature or full grown state, an animal grows by an addition of cells made to its various organs—homogeneous cells elaborated by its own fabric, and furnished to every organ, to every tissue, by which organs and tissues these hemogeneous cells are assimilated to their own peculiar nature.

Hence, the same law under which the new being is started, prevails throughout all its phases, all its metamorphoses, and all its stages of growth; in other words, *the means which nature employs in view of the perpetuation of the species are the same as those made use of by her in the process of the growth and sustenance of material or physical life.*

VI.

If the primordial cell is considered as the elementary physiological particle of the organic tissues, then we may safely say that, physiologically speaking, there are no organic elements properly so called; for, however simple a cell may be, its existence implies the presence of two substances of an apparently elementary nature—an internal and enclosed substance, and an external and enclosing one. Thus a primordial cell does not arise from one substance: two substances are required to effect the formation of primordial cells.

It has been shown that the two substances which give origin to the primordial cells, are, oil on one side, and, albumen on the other.

Oil and albumen, therefore, constitute the organic primary materials; but neither oil nor albumen is itself a simple body or element.

For, oily matters are composed of carbon, hydrogen, and oxygen;

And albumen of carbon, hydrogen, oxygen, and nitrogen.

Consequently the true elements of organic substances are the same as those that enter into the constitution of most inorganic bodies.

VII.

Here we touch upon a wide field of research.

Under this heading is comprised all that diversity of movements and motions which give to animated nature its *animated aspect.*

There are first the movements of every animal as a whole; and then the movements of its parts or organs each individually: all of which are at the will of the animal.

And there are the motions of some of its organs not under the control of its will.

The movements of an animal as a whole, and the various motions of its organs individually, constitute the *zoölogical aspect* of the mechanics of life.*

Behind (we might say at the bottom of) these tangible movements and motions of complex parts, there is a molecular motion (if we may use such an expression) of the constituent particles of each organ or part, which constitutes the *physiological aspect* of these same mechanics of life.

* The zoological aspect of the mechanics of life will form the subject of a subsequent memoir.

But each motion implies a motory power. Let us inquire into this.

The constituent particles of all organic tissues and organs are, as already stated, the animal cells. Animal cells possess in themselves their own power of motion, a motion *per se*, inherent to each cell. A latent power as it were, which, upon the application of an impulsive principle transmitted to the cell through its walls, will expand it and thus cause it to move; and this motion, on being communicated to the adjoining particles or cells, will set in motion an entire organ.

The impulsive principle is altogether physical in its nature. Electricity under some sort of form pervades animated bodies. Chemical combustion results from its evolution. The motion, at first, is molecular: many cells expand to bursting; in bursting, they are dissolved, and their materials used as fuel; their constituent elements resolve themselves into gases, and these constitute the actual motory agents of the organs.

Carbonic acid gas is the most prominent; its presence in the body is thus connected with the body's motions;

Just as the materials consumed as fuel are connected with the nutritive process, as will be shown further on.

The physical history of an animated being, while under a tangible and physical aspect, consists in the combination of a few chemical elements as the foundation of its material frame, intermixed with other inorganic elements of an accessory importance. These elements are the same as pervade the other kingdoms of nature, passing here through a series of metamorphoses or compounds of a gradually higher and more complex degree, and redissolving into primary elements at the terminus of the duration of material life.

Let it be stated, in passing, that, to the animated structure of physical bodies is superadded in human beings a soul, or moral nature, which occupies in them a temporary abode.

Now then, in order to harmonize this hasty sketch with the idea by which we are guided, we resume as follows:

In all living bodies there is a wearing away of the particles of which their various organs are composed.

Every physical motion, every action of the mind, involves the dissolution, the using up of materials that belong to the organ which is called into action.

The organs being composed of cells or their derivatives, the wearing away of their constituent particles, therefore, is nothing less than the using up of organic cells or their derivatives in a given quantity, always equivalent to the act performed.

VIII.

If organized bodies, therefore, did not receive new materials to promote their economy, there would be a gradual decline in their activity, until life would entirely cease. In like manner an inorganic body depends upon a constant renewal of the force which caused it to move, to keep in motion; otherwise it would gradually slacken its course, and come to a state of absolute rest.

Absolute rest is death to organized bodies.

Living bodies, consequently, require nourishment, to maintain their activity, as well as for completing their growth. They consume materials whilst growing; accordingly they require more nourishment during their immature than in their mature condition, having to provide simultaneously for the addition of substance by which their mass is increased, and the replacing of the substance used up by their activity.

And thus we see animals borrowing materials from the surrounding world, and introducing them into a cavity of their body, known as the stomach, therein to undergo a process of elaboration, or transformation, before they are fit to be appropriated by the various tissues or organs in need of them.

The materials borrowed from the external world and introduced into the animal fabric are most varied in their character. By a large number of animals a certain selection is made, some of them depending exclusively upon one kind of food, and some on another; some appropriate vegetable and others animal substances.

But whichever be the case, let an animal be fed upon all sorts of substances, or upon one substance exclusively, the food taken is different in its structure from the constituent substance of the species which appropriates it to its use,—each species having its peculiar constituent organic cells. Before these new materials can be of any avail to the fabric into which they are introduced, they must necessarily undergo a process of elaboration; that is to say, their specific nature must yield its state of being and assume a new form, a new state of being, in order to become a fit constituent part of a body differently shaped, and endowed with different wants and propensities.

One example will illustrate this train of thought. Let us suppose a meadow in which grass is luxuriantly growing. Whether the grasses be of various kinds or of one kind only, the bearing will be the same: this will constitute a vegetable food of one common class. Now let a horse, an ox, a sheep, and a goat, graze together, in such a pasture, side by side. These animals will take the same food, appropriating it to their economy according to the same general process. What will be the result? four kinds of flesh are formed as widely different from each other as these species of animal are distinct; distinct in their flavor, distinct in every particular of their intimate structure, yet flesh in every case.

The physical life of the horse, the ox, the sheep, and the goat, is sustained, and the growth of these creatures promoted, in each according to its kind, though surrounded by identical external circumstances, and furnished with the same food.

Again, turn your thoughts for a moment to what is daily taking place in a river or in a lake, along a sea-coast or in a bay. Each of these media is peopled with a host of beings belonging to various classes, orders, and families. Their circumstances of life are identical; their wants and propensities are varied as their forms. They prey upon one another; they appropriate and transform organic substances according to their own specific nature, with a constancy, a fixity of purpose, over which time has no control. A salmon, remains a salmon; a white-fish, a white-fish; &c., &c., to the perpetuity of their races.

The signification of all this is self-evident, forcibly plain: each animal, in its kind, is endowed with an immaterial and specific principle, working out its destiny upon this planet according to a preordained plan, and a predetermined direction imparted to it at the beginning of the actual existing order of things.

This working up of matter which each species models according to its own image, is one of the most powerful arguments in favor of the existence of an immaterial and independent principle in each species, and also of the existence above them all of another great principle, self-conscient, who, by His sole will, has made them what they are.

Beyond the phenomena of nutrition we touch the bounds of moral life. If we may explain the physical being in its diverse manifestations or aspects, the genesis of moral being is not within our reach. Here the true naturalist sets aside his tools, and, with submissive thoughts, glorifies his Maker.

IX.

The nutrient fluid, when considered in the animal kingdom as a whole, presents itself under three typical forms, from its simplest expression in the polyps, up to its most complex state, in the vertebrata, of which man is the head.

These diverse phases of the circulation are well known to physiologists.

In polyps or radiata of an inferior grade, in some mollusca and some crustacea, the nutrient fluid circulates as *chyme*. Now, wherever the circulation is chimiferous, there are not proper organs of respiration: water enters the body through the mouth or through the walls of the body, mixes directly with the chyme, and circulates with it.

The chimiferous circulation is met with in aquatic types only.

In the highest radiata, mollusca, and most articulata, the nutrient fluid circulates as *chyle*. There are special reservoirs for the assimilation and

the circulation of that fluid; and, as a necessary consequence, there are organs of respiration. Moreover, wherever a chyliferous system exist, there is likewise a lymphatic system.

The chyliferous circulation is met with in terrestrial as well as in aquatic types.

The chyle may assume most varied and sometimes vivid colors.

It is in vertebrata alone that the nutrient fluid circulates as *blood.* The elaboration of this fluid undergoes here the most complete morphology. Organs of respiration of two sorts, gills and lungs; a system of vessels to transport the chyle; a double circulation, arterial and venous; a system of vessels carrying lymph,—attest by their presence that the elaboration of the nutrient fluid passes through a longer and more complex process than that heretofore alluded to. True blood is the last phase in the morphology of the nutrient fluid. It is only by analogy that blood in the articulata, mollusca, and radiata, is spoken of.

To recall now briefly, and in a physiological point of view, the constituent parts of the blood, we have:

A *liquor sanguinis* composed of water and of albumen, in which float the so-called corpuscles, or blood-disks, the fibrine, and likewise some mineral salts.

The corpuscles are of a peculiar character in each animal; they are almost all alike in shape and size in any given species. There are two kinds of corpuscles, or blood-disks, the red and the white; the red being by far the most numerous.

The *red corpuscles* contain in their interior either a colorless and transparent nucleus, generally spherical in shape, sometimes ovate; or else several nuclei, agglomerated, resembling a diminutive mulberry.

The *white corpuscles*, by their small number, appear in some sort lost in the midst of the red. They are generally smaller, scarcely ever as large as the red; their shape is nearly circular, their size constant and uniform. Their contents consist always of several scattered and very distinct nuclei. They have been designated under the names of chyliferous and lymphatic corpuscles; they are altogether different from the red corpuscles in their structure as also in the part which they play in the animal economy.

The *fibrine* has always been considered as the nutritive portion of the blood, as the essential part, that part which is taken up by the fabric in the act of nutrition, that is to say in the growth and in the reparations of the losses which all the organs sustain. The fact that fibrine is less abundant in the venous than in the arterial blood, would alone suffice to prove that this substance is appropriated by the animal fabric. Fibrine is considered as a plastic structureless fluid, the solidification of which, in the tissues being the final act in which it participates. To use the expression of physiologists, it is a sort of *vital crystallization*, which vital crystallization of the fibrine in the tissues would explain the process of nutrition.

X.

Let us now follow the transformation of the substances taken as food for the double purpose of repairing the losses of the animal fabric or promoting the wants of its economy, and of providing materials for its growth.

The digestive system is the laboratory of matter, the retort (we would like to say) in which the substances are elaborated.

The office of the stomach is to digest; in other words to reduce to an elementary pulp the various cells constituting the substances introduced and called upon to furnish, to the system of circulation, new nutritive materials.

The pulp resulting from the digestion is the *chyme*. In passing through the intestines a separation is made; a portion is absorbed by a system of vessels, known as the lacteals, whose office it is to carry it into the veins. The portion of the chyme which is absorbed is the *chyle*. The other portion is expelled from the economy as a useless residue which the chemical process of digestion failed to dissolve.

The chyle, then, is the only portion of the digested food which is appropriated by the fabric; that chyle is now to be assimilated in order to become nutritive.

But the chyle in its nature consists chiefly of liquid fat, or oil: as such it is not nutritive; and we know that the nutritive part of the blood, the fibrine, is neither liquid fat nor oil.

Let us, therefore, return for a moment to the lacteal vessels, through which the chyle is forced into the venous blood.

Previous to the emptying of the lacteals into the veins (similar to small bodies of water pouring their element into larger rivers), they have met with the lymphatic vessels, the contents of which are thus added to their own as they meet with it in their onward course.

The contents of the lymphatic vessels consists of lymph; the nature of the lymph is albuminous: lymph is pure albumen.

The lymph is no sooner poured into the lacteals, than the two liquids, lymph and chyle, combine. The result of this combination is the formation of cells—of primordial cells, in every respect similar to the primordial cells which may be produced in an artificial way, in bringing into contact albumen and liquid fat, as shown by experiments above alluded to.

Primordial cells may be formed in the lacteals also under the following circumstances:

It must strike every one that albumen is also supplied to the wants of the fabric through the digestive apparatus. When therefore albuminous matter predominates in the digestion, it is absorbed by the lacteals; in

which, when fatty matter is present, cells are instantaneously formed. When albumen is in excess in the digestion, it is carried as such into the circulation, thus supplying the liquor sanguinis with the amount of that substance which is required to constitute the serum.

Again, when the albumen carried by the lymphatics is likewise in excess over the fatty matter of the lacteals, it passes as such into the liquor sanguinis for the same purpose of forming the serum.

The primordial cells now enter the venous circulation and are carried, more or less directly, to the lungs; in which organs, their previous pinkish color is changed into the red hue which characterizes them. Henceforth they are called the *red corpuscles of the blood.*

The red corpuscles of the blood, consequently are primordial organic cells. Embryology alone could settle this problem. It is not surprising, therefore, that their true nature should have been misunderstood when first discovered, since at that period embryology had not assumed its rank amongst natural sciences. Yet it appears singular that the experiments of Dr. Ascherson did not give the hint to physiologists; all of whom were conversant with the fact that cells were formed in the lacteals upon the admixture of the lymph and the chyle,—who knew that the lymph was nothing but albumen, and that the chyle was chiefly liquid fat.

But let us not lose sight of these so-called red corpuscles, now floating in the midst of the nutrient fluid. The part which they play in the animal economy is to be further investigated. Their interior has become a new centre of elaboration, in which nuclei develope according to the general law adverted to above. These nuclei are a generation of minute cells, afterwards to float likewise in the liquor sanguinis, when the primitive envelope or membrane of the corpuscles shall have been dissolved. This dissolution of the primordial cells (corpuscles) of the nutrient fluid, in all probability, takes place in the lungs, subsequently to a first or second circuit in the reservoirs of the circulation. It is during that circuit that their nuclei appear and develope into cells of a second generation, to constitute the fibrine upon the rupture of these corpuscles.

The prime office of the primordial cells, then, is to elaborate a generation of cells, which are the constitutive materials of the fibrine; the fibrine is the assemblage of these minute and homogenous cells formed within the red corpuscles or primordial cells of the blood or nutrient fluid.

Besides the elaboration of the fibrine, primordial cells have a secondary office to perform. They convene into the economy a supply of oxygen, and bring back from it, for the purpose of being expelled, the excess of carbonic acid not wanted therein. Not improbably it is during this giving away of the carbonic acid gas, that the primitive envelope of these cells is burned and thus dissolved by the pulmonary combustion, setting free the young cellules they contain, henceforth to float freely in the stream of the liquor sanguinis as fibrine.

The fibrine is acknowledged by general consent to be the nutritive

portion of the nutrient fluid. While under the immediate action of the organism it is disseminated throughout the whole bulk of the nourishing fluid or blood in the shape of minute cellules. When it is withdrawn from the living fabric and an attempt be made to separate the diverse elements of that fluid, these minute cellules agglomerate together, constituting what is termed the *clot*, with which is always mixed a certain amount of albumen.

Now, the fibrine is to go to the tissues under the shape of minute cells passing through the walls of the capillary vessels. These cells take the place of the dissolved particles, turning into flesh, bone, nerve, &c., &c., according to the organ to which they happen to be carried. For, as long as they circulate in the blood, they are perfectly homogenous and ready to be transformed into any of the various tissues which constitute the organic frame. Each organ, each tissue, has its own peculiar cellular structure. The living principle of the animal fabric provides for that diversity. When, therefore, the cells of the fibrine reach an organ either to repair its losses or to promote its growth, they undergo a metamorphosis by which they are assimilated to the nature and structure of that organ or that tissue.

The cells of the fibrine being in fact the elementary materials of which physical bodies owe their existence, the name of *protean cells* is deemed well appropriated to designate them.

In calling the cells of the fibrine protean cells, we wish it to be understood, that that name alludes simply to the part which they perform in the economy of living bodies,—that of being the primary materials out of which their entire frame is built up,—making no allusion whatever, to the organic proteine of some chemists. If, however, we go any further inquiring into the constitutive elements of these cells, we will find for answer the words *oxygen*, *hydrogen*, *carbon*, and *nitrogen!* as fundamental constituents of all organic bodies.

The entire economy of organic bodies, the living fabric, therefore, is but an elaboration of cells; the immaterial principle which resides within them all, disposes of the cells according to a plan stamped upon each species, to suit their wants, their aptitudes, their propensities, by which all organs are necessary to one another in the animal structure, and all animals necessary to one another in the plan of creation.

Through this cellular process of the fabric there is a constant and gradual renewing of all the constituent particles of organic bodies; so that it may truly be said that all the cells which constitute now any given organism, will, after the lapse of a certain period—perhaps of years—have been entirely replaced by other cells.

XI.

Chemical analyses of the various parts and organs, constituting the frame-work known as the animal fabric, have revealed to us the presence

therein of several other mineral elements or compounds besides carbon, hydrogen, oxygen, and nitrogen. The latter form the basis of the organic frame; the former are disseminated through it.

They are met with either as earths forming a share of the structure of several solid organs, or else as salts and acids, floating in the various liquids.

Some of them are of prime necessity for the welfare of the animal fabric in its highest grade of organization. Thus phosphorus is necessary to the bony frame of vertebrates, and calcium is necessary to the exoskeleton of molluscs and radiates.

Others are altogether accessory or accidental, having found their way into the economy in combination with the food that each living being is compelled to absorb for the promotion of its activity.

Digestion, in elaborating the raw materials, makes a primary separation; a residuum is thrown out from the apparatus, consisting chiefly of particles undecomposed and too large to enter into the circulation.

Such of these accessory materials as find their way into the circulation, together with those needed by the economy, have now to pass through a series of glands, or strainers, as it were; by which they are arrested, or rather led in a special direction, sometimes being made subservient to a minor and secondary function of the organism, and at others being rapidly rejected from the economy as either useless or deleterious.

In the gastric juice we find chloride of sodium, potassium, sulphuric, phosphoric, carbonic, and other acids,—to assist in decomposing the raw material of the food, while in the stomach or retort of the digestive apparatus.

The minerals found in the blood are potassium, sodium, calcium, magnesium, iron, silicium, chlorine, sulphur, and phosphorus, together with carbonic acid.

The blood in its passage through the hepatic gland yields silicium, phosphorus, and sulphur, in the form of acids; carbonic acid also.

In passing through the renal glands, the blood gives off chlorine, and phosphoric and sulphuric acids.

The mammary glands extract sulphuric, phosphoric, and carbonic acids.

Such is the hasty and imperfect sketch of a chapter that would form, together with the one just preceeding, the subject of a book of the most vivid interest The doctrine of chemical equivalents is very intimately connected with it, and, in its application to therapeutical medecine, would furnish us with invaluable hints for the administration of medicaments in the pathological conditions of the organic fabric.

XII.

A few words in reference to the white corpuscles of the blood are deemed in place. These also are cells; but not primordial ones. They originate from protean cells, which, not having found their way out of the capillary system of vessels, and consequently remaining in the liquor sanguinis, without any ulterior function to perform, outgrow their vital circle. The result of this state of things is their transformation into transparent cells, provided with several well defined nuclei.

Morphologically speaking, therefore, the white corpuscles of the blood are genuine epithelian cells.

The preponderance in the blood of white corpuscles would indicate either an excess of protean cells (fibrine) or else a pathological condition of the system. This requires special therapeutical attention.

The epithelian cells of the organic tissues we know to perform a temporary office or function; they afford either an outer or an inner lining and protective coating to several organs. They lead an ephemeral existence; their prototypes are protean cells, brought through the usual channels of the circulation to the organs where they occur. Epithelian cells are constantly casted away from the external surface of the body, as likewise from the internal mucous membranes. The life of these cells is rapid and brief; no sooner is their temporary office performed than they are removed from the animal fabric, by a direct act of the latter.

Thus the epithelian cells of the blood (the white corpuscles) are removed from that liquid, in which they have no further end to attain, through the agency of the glands, or natural strainers: mucus and epithelium being met with in the gastric juice, saliva, bile, and urine.

XIII.

It is recorded in the text-books of physiology that lymph is formed in every part of the body, at the periphery or confine of all the organs, and that that lymph is carried back by a system of vessels, the lymphatics, into the general circulation.

It is, indeed, a fact, that there are lymphatic vessels carrying lymph and pouring it into the venous system, as seen above. But to say that lymph is formed at the periphery of all the organs, is to imply that the body itself secretes or creates it, since no special organ for the secretion of this substance is found any where to exist.

We will not venture to deny absolutely the power of the animal fabric to produce albumen, that is, to make it out of the oxygen, hydrogen,

carbon, and nitrogen, coexisting within it; yet we cannot help thinking that such an act is not performed at the periphery of the tissues or organs.

In the theory we have endeavored to unfold in these pages, this phenomenon of lymphatic circulation is to be accounted for in the following manner:

The blood, or nutrient fluid, is composed of a given quantity of serum, the liquor sanguinis proper; that serum being nothing else but albumen diluted in water. The office of the liquor sanguinis, or serum, is to keep apart the protean cells, in other words to prevent the fibrine from agglomerating: a state of things towards which it is very prone. The passage of the protean cells (fibrine) through the walls of the capillaries is accompanied by the serum until they reach their location or destination beyond their reservoirs. When this is attained, the presence of the serum being no longer required,—since the protean cells are now incorporated in the organs and tissues,—it dissolves: its watery element passes away; a portion in the shape of perspiration through the outer integument, and another to lubricate the viscera and other organs requiring lubrication; whilst the albumen in the form of lymph is immediately absorbed and carried back, by the lymphatic vessels, into the venous blood, as already alluded to in speaking of the lacteals and chyle, when the part which lymph (albumen) plays in the animal economy was thoroughly examined.

So important, indeed, is the office which albumen performs in the fabric, that we need not be surprised seeing a system of vessels peculiarly adapted for storing it up and keeping it in readiness for future wants.

XIV.

It is important now to show that the genesis of the system of circulation and of the nutrient fluid is consistent with the views which we have taken of the phenomena of physical life.

There is a moment in the history of the embryo when circulation does not exist. That function, being subordinate to others of a higher grade of importance, makes its appearance in a due time.

The heart is the central organ of circulation; the heart will appear before the arteries and veins. Its first manifestation is a group of cells situated in that region of the body which it will ultimately occupy. This group of cells increases; the next step will show it subjected to isochronic contractions. Then its centre becomes hollow. No sooner is a cavity formed, than loose organic cells will appear in it, and henceforth remain under the exclusive control of the contractions of the heart, for such we must now call that cellular organ. Creek-like channels will next shoot off from this central organ, and the cells therein contained (which are

nothing else but the primitive corpuscles of the blood) will be forced into these channels (the primitive arteries) at each systolic contraction; receding back into the heart at each diastole. This action keeps going on until the arteries reach the periphery of the system, when recurrent channels (the veins) are formed, bringing the cells back into the heart from a direction the opposite of that through which they proceeded forth.

The system of circulation will, it is true, undergo some minor modifications, contingent upon the full development of the various organs of the fabric; but, as such, it is complete, there existing a central organ which forces the fluid through a system of vessels towards the periphery of the organism, whence that fluid returns to the central organ through another system of vessels.

So much for the genesis of the apparatus or reservoirs of the circulation.

The primitive liquid which is put into circulation is essentially composed of organic cells, yielded by the embryonic mass itself,—of cells primordial in their nature, being the initial corpuscles of the blood or nourishing fluid.

Thus, the genesis of the nutrient fluid.

The analogy is complete; the corpuscles of the blood are organic cells.

Meanwhile the organs of respiration are developing, and in due time the nutrient fluid is carried into them for the purpose of undergoing the process of respiration. What that process really is we have adverted to above.

XV.

The vitellus is the substance prepared and stored up by the organism in view of a future being, which is, physically speaking, to be exclusively formed out of it.

The fibrine is the substance prepared by the organism in view of the physical wants of the same new being after hatching; which is nourished, sustained, and increased in bulk out of it exclusively.

The fibrine of the blood and the vitellus or yelk of the egg have essentially the same organic structure, effecting a similar end, performing a similar act, and accordingly having the same signification.

The constituent parts of the yelk are the well known cells of the yelk, or vitelline cells.

The constituent parts of the fibrine we have ascertained to be small cells. This fact has already been stated.

The vitelline cells have, previous to fecundation, a state of repose, of quiescence, of complete rest; therefore they may easily be studied.

The protean cells are in a state of constant activity and proneness towards change, which makes it very difficult to observe them in their primitive condition; they remaining such only while floating in the liquor sanguinis. Again, their very dissemination in the liquor sanguinis is an obstacle in the way of getting hold of them. While undergoing the process of separation, they lose their primitive aspect; hence their identity with the vitelline cells does not strike one as quite so evident.

XVI.

While tracing the "Embryonic development of *Planocera elliptica*"* we have figured and described a peculiar kind of white and transparent cells (already brought to notice, but misunderstood by former writers on embryology) under the name of "floating cells," from the circumstance of their being found freely floating in the midst of the albuminous zone surrounding the yelk or embryonic sphere. There is no doubt in our mind as to their true orgin: being genuine vitelline cells dropped from the vitelline mass into the albumen, which cells upon their complete separation from the living sphere, remain with no further function to perform. Their innate organic power will soon exhaust itself; the consequence will be an expansion of their membrane and the outgrowth of their nuclei, thus becoming epithelian cells.

"Floating cells" may likewise be found in the centre of the vitellus during the period of its greatest effervescence, immediately prior to the first manifestation of the embryo. The vitellus at that time becoming hollow, there are chances for some vitelline cells to lose their adherence; and in falling into the cavity just formed, they will outgrow their activity. They may occasionally be seen emerging from the embryonic mass, and entering the albuminous zone around the yelk.

"Floating cells" have been observed during the phases of the division (or cleavage) of the yelk; while those phases are going on, vitelline cells have a similar chance to separate from the general mass and undergo a premature development.

So much for the embryonic "floating cells." Now, for the white corpuscles of the blood:

Such of the protean cells (fibrine) as are permitted to sojourn in the nourishing fluid beyond a given period without passing through the capillary vessels, and thus prevented from performing the function for which they were prepared by the organic fabric, will now undergo the process of hasty and premature development, consisting in the extension of

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* Journal of the Academy of Natural Sciences of Philadelphia. New Series. Vol. II, 1854, with three plates.

their membrane and outgrowth of their nuclei—thus becoming epithelian cells.

The structural resemblance between the "floating cells" and the white corpuscles of the blood, as also between both of these and the epithelian cells of the organic tissues, is placed beyond any reasonable doubt. Consequently:

The white corpuscles of the blood are wasted protean cells;

The embryonic floating cells are wasted vitelline cells;

And both, the white corpuscles of the blood and the embryonic floating cells, are truly epithelian in their nature.

XVII.

Again, the epithelian cells of the organic tissues are wasted organic cells. They are formed at the periphery of the organs or else along the parietes of organic membranes. Unprotected on one side, and on the other in contact with the body of the organ in full activity, their growth is quickened and their vital power soon exhausted; they become deciduous, fall, and are carried away through the natural channels of the fabric.

Epithelian cells, however, are not altogether useless in the economy of living bodies; they afford a protective surface to several membranes and organs against the deleterious effects of the surrounding media. Upon the surface of some membranes they acquire vibrilla, which by their motion promote the circulation of certain fluids. Even in some embryos, vibrilla may be observed upon given points of their periphery, which for a limited period perform the sole locomotory functions extant.

The phenomenon of epithelian growth is a permanent and important function of the animal fabric; the epithelian cells themselves are temporary and ephemeral, the nutrient fluid behind the tissues being always ready to supply their place when vacated.

XVIII.

Nutrition is the ultimate word of physiology. The ultimate word of physiology is, in principle, the first word of therapeuthical medicine as a science. Without the avail of physiology, the latter is but an art.

Surgery, or operative medicine, rests entirely upon anatomy. The better an organism is known to the operator, the better will his operations be performed. In the same sense, therefore, we may say that the ultimate word of anatomy is the first word of surgery: and at the bottom of both, physiology and medicine both therapeuthical and operative, we meet with embryology.

Practitioners all agree that a scrupulous attention is to be given to the *temperaments* in a therapeutical point of view.

Temperaments have their essential cause in a *qualitative difference* in the solids and liquids which constitute the human frame, and not in a *structural difference*: the structure is identical in all individuals. Temperaments, therefore, belong to the domain of physiology.

A temperament which is said to be *phlegmatic* or *lymphatic*, is owing to the presence in the circulation of a surplus of albumen, which renders the nutritive element defective and inadequate to fulfil its functions.

By a protracted continuance of the lymphatic element in the system, the temperament becomes what is termed *nervous*. The organic fabric is sensitive and excitable, because of the defective and impoverished state of the nutritive principle.

The temperament termed *sanguineous* is brought about by a surplus of blood corpuscles and hence of fibrine. The nutritive element is overwhelmingly rich.

By a long continuance of the sanguineous temperament, the latter becomes *bilious*. A copious secretion of bile is the necessary consequence of such a state of things. It reaches its *melancholic* phase when a surplus of fatty matters is present in the system, by which the hepatic function is rendered too laborious. A *nervous* phase may likewise follow, owing to the morbid condition of the phase just preceding.

Thus temperament may be classed into two categories:

First, Lymphatic, with a nervous phase.

Second, Sanguineous, with three phases, a bilious, a melancholic, and a nervous.

Physical bodies may be in a consumptive condition and unattended with any other disease. They may emaciate merely because the materials supplied are in a smaller proportion than the materials consumed.

The general treatment to be followed speaks for itself. In a plain case of consumption resulting from the wasting away of a greater amount of organic matter than is actually elaborated by the animal fabric, prescribe a diet rich in albuminous and fatty substances. Should the digestive system lack tone, resort to tonics.

So much for the supply of proper materials: but these have to be properly assimilated; and in case of failure of the fabric to do so, alcohols are to be added to carry the process through.

To a lymphatic temperament let fatty substances predominate.

When the temperament happens to be nervous, nervous stimulants, which are to be selected, will form a part of the treatment.

A genuine sanguineous temperament is not apt to be consumptive.

But when the latter reaches its bilious phase, acid draughts may be given: the system, however, is not prone towards consumption.

During the melancholic phase of the sanguineous temperaments the diet should be more of an albuminous than oleaginous character, adding tonics, especially when a tendency towards a nervous phase becomes evident.

The *phthisis pulmonalis* is generated by the disposition, in the organs of respiration, of amorphic or unorganized substances contained in the nutrient fluid, such as lymph or more properly albumen. The tubercular deposit is assisted by a residuum of the exuviæ of the red corpuscles, brought about by an imperfect combustion, which failed in reducing the latter into volatile elements to be expelled through the natural channels of these organs.

The chief causes of this disease, therefore, reside in an imperfectly assimilated food, combined with a deficiency of combustible elements. Both of these causes may act simultaneously, or either one of them alone.

There are cases of consumption accompanied by collateral diseases. One branch of the elaborating system may be diversely affected by lesions or obstructions; a peculiar organ may be defective in its development or the performance of its functions; and many other causes of disturbance may exist. All these are to be treated as special diseases, according to special methods, which shall in no way conflict with the general treatment pertinent to genuine consumption.

A large field of research is here thrown open to chemists, physiologists, and physicians. Many inquiries and problems, not yet understood, will surely be answered by careful investigations and a sound appreciation of facts.

APPENDIX.

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It is a sufficiently well known fact that the general views held respecting the animal kingdom as a whole, actually divide naturalists into two camps.

There are those who regard it as constituting one uninterrupted series, beginning with the polyp and ascending to man;

And those who subdivide it into four primary, parallel, distinct, and unconnected groups or series.

These questions are not without importance: they approach near to the designs of the creation, both physical and moral.

They will chiefly find a solution in the geological history of our planet and partly also, in the anatomical investigation of existing faunas.

Led by the observations which precede into a comparative study of the various apparatus which constitute the animal fabric, we have sketched out the following programme for further investigations.

In tracing out the history of each apparatus as laid down beneath, we shall be in possession of the very data which are demanded for the satisfactory solution of this much disputed scheme.

PRODROMUS OF A PHILOSOPHIC GENERAL ANATOMY AND PHYSIOLOGY.

I. Digestive system and its dependencies.

A. Alimentation:—morphology of its apparatus in:

1. Radiata.
2. Mollusca.
3. Articulata.
4. Vertebrata.
   - *a.* Mastication.
   - *b.* Deglutition.
   - *c.* Digestion.
   - *d.* Chymification.
   - *e.* Chylification.
   - *f.* Nutrient fluid.

B. Circulation:—morphology of its apparatus in:

1. Radiata.
2. Mollusca.
3. Articutala.
4. Vertebrata.

α. Nutrient fluid circulating as:
  a. Chyme.
  b. Chyle.
  c. Blood.
β. Lymphatic system and lymph.

C. Respiration:—morphology of its apparatus in:
  1. Radiata.
  2. Mollusca.
  3. Articulata.
  4. Vertebrata.
α. Branchial respiration.
β. Pulmonary respiration.
γ. Branchial and pulmonary respiration in coexistence.

E. Nutrition similar in the whole animal kingdom.

F. Reproduction:—morphology of the sexual organs in:
  1. Radiata.
  2. Mollusca.
  3. Articulata.
  4. Vertebrata.
α. Ovaries. } Their structures and functions.
β. Spermaries. }

G. Glands and Secretions:—morphology of their structure in:
  1. Radiata.
  2. Mollusca.
  3. Articulata.
  4. Vertebrata.
α. Secretions for local purposes and wants of the individual.
  a. Salivary glands and saliva, connected with mastication and deglutition.
  b. Gastric glands and juice. } Connected with digestion.
  c. Pancreatic gland and fluid }
  d. Hepatic gland and bile. }
  e. Mucous glands and fluid.
  f. Lachrymal glands and tears.
β. Secretions for the perpetuation of the species.
  a. Ovaries and ova—office of the female.
  b. Spermaries and spermatic particles—office of the male.
  c. Mammary glands, and milk temporarily secreted by the female.
γ. Secretions rejected as useless.
  a. Fæces—generally in a solid state.
  b. Urine—in a liquid state.
  c. Perspiration—in a state of vapor.
  d. Carbonic acid—in a state of gas.

II. Nervous system and organs of senses:—morphology in:
1. Radiata.
2. Mollusca.
3. Articulata.
4. Vertebrata.

α. Encephalon.
a. Olfactory nerve and organ of smell.
b. Optic nerve and organ of sight.
c. Auditory nerve and organ of hearing.
d. Nerves and organ of taste.
e. Other nerves of the encephalon.

β. Spinal chord and spinal nerves.

γ. Sympathetic nerve.

δ. Corpuscles of Pacini.
f. Sense of the touch.

III. Osseous system.
Bony frame of Vertebrata.

IV. Calcareous and horny systems in:
1. Radiata.
2. Mollusca.
3. Articulata.
4. Vertebrata.

V. Muscular system: its morphology in:
1. Radiata.
2. Mollusca.
3. Articulata.
4. Vertebrata.

VI. Organs of movement, and locomotion in:
1. Radiata.
2. Mollusca.
3. Articulata.
4. Vertebrata.

VII. Histology:—microscopic structure.

VIII. Embryology.
a. History of the egg prior to its maturity.
b. History of spermatic particles prior to their maturity.
c. Fecundation.
d. Formation and development of the embryo in:
1. Radiata.
2. Mollusca.
3. Articulata.
4. Vertebrata.